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Implementation of Zero Liquid Discharge Systems in Russian Industry

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Abstract. The article focuses on the implementation of zero liquid discharge (ZLD) systems precluding the pollutant release to the environment at metallurgical, machine-building and metalworking enterprises. The need to change over to such systems is due to two main factors: 1. Significant savings in fresh water used in production; 2. A decrease in the number of all kinds of pollutants reaching the environment with various discharges (purified, insufficiently purified and completely untreated). The main feature of ZLD systems at industrial enterprises is the presence of tailing management facilities, e. g. concentrated wastewater treatment facilities; industrial wastewater sludge treatment facilities; non-recyclable oily wastewater and sludge incineration facilities; reclaimed (recycled) industrial wastewater treatment facilities etc. The development stages of ZLD systems in Russia are presented. In 1973, for the first time in the world's practice, in the Verkh-Isetsy Metallurgical Plant in the city of Sverdlovsk (now Yekaterinburg), the ZLD developed by Prof. V. I. Aksenov and his colleagues was launched and has successfully operated in the cold rolled transformer steel workshop. As an example of wastewater treatment facility as part of a ZLD system, some technical installation solutions are described in order to treat chemically contaminated acid ferrous-containing wastewater generated in pickling carbon steel. The focus is on the feasibility of implementing local ZLD systems instead of central ZLD systems. The advantages of such local systems are: possible regenerating exhausted process solutions at the place of their formation, obtaining demineralized water, the local treatment of chemically polluted wastewater, lower investment and operating costs.

Keywords: Steel pickling; Industrial wastewater treatment; Sludge dewatering; Zero liquid discharge system

1. Introduction

The 1990s of the last century were marked by the widespread transition of industrial enterprises of the world's developed countries to the zero liquid discharge (ZLD) systems to prevent the discharge of pollutants into the environment. One of the first formal zero waste policies was created in 1995 when Canberra, Australia endorsed a goal of «No Waste by 2010» [1].

The need to switch to ZLD systems is due to two main factors [2]:

- significant savings in fresh water used in production;
- a decrease in the number of all kinds of pollutants entering the environment with various discharges (purified, insufficiently purified and completely untreated).



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In developed countries, the constraints preventing an increase in water consumption always include the high cost of fresh (natural) water, huge penalties and other consequences of a discharge into waters (discharges in excess of permitted pollutant limits) and instant adverse publicity. Therefore, the ZLD systems are being built in the USA, EC etc., after which efforts are taken to use the treated water to the fullest extent [3].

The transition to ZLD systems involves the introduction in industrial enterprises of:

- the process equipment for the operation of which water is not required (for example, dry gas cleaning installations to replace wet gas cleaning installations) or less water is needed. In addition to the reduced water consumption, such equipment makes it possible to eliminate the formation of industrial wastewaters or significantly reduces industrial wastewater generation;
- the local open, closed and combined water recirculating cooling systems in individual production units and workshops (our experience shows that investing in such cycles pays off within a few months);
- local industrial wastewater treatment facilities for certain categories of industrial wastewaters containing heavy metal compounds, organic constituents etc., and end-of-pipe industrial wastewater treatment facilities for release from an enterprise to wastewaters not contaminated by any specific constituents (for example, surface stormwater runoff);
- treatment facilities for surface stormwater runoff and (or) treatment facilities for the advanced treatment of municipal wastewater designed to use purified water after those facilities to replace fresh (natural) water;
- units designed to eliminate the accumulated environmental damage making it possible to obtain some useful industrial products from industrial wastewater sludges stored for a long time;
- units designed to treat the industrial wastewater sludges that eliminating the need to store the industrial wastewater sludges in hazardous waste landfills.

At the same time, the ZLD systems implementation in the Russian industrial enterprises should be preceded by fairly costly preliminary overhaul or replacement of the main production facilities of water industry systems (pumps and pumping stations, water cooling towers, wastewater clarifiers etc.), elimination of water leaks and unauthorised pollutant discharges into water bodies and on the terrain (for example, regular industrial wastewater overflow from clarifiers) [4]. In addition, it is also necessary to carry out administrative and technical measures to bring the environmental documentation available at the enterprises in accordance with the existing provisions of the federal law of Russian Federation «On Environmental Protection» and other related regulatory documents on the best available techniques (BAT) implementation.

2. Features of the Zero Liquid Discharge Systems of Industrial Enterprises

To make a ZLD system of an industrial enterprise, tailing management facilities are used:

- units designed to treat the concentrated wastewater (for example, spent solutions from the pickling processes and the plating processes);
- units for the treatment of industrial wastewater sludges, the operation of which results in not waste being sent to a hazardous waste landfill but recoverable industrial products;
- units for the incineration of unrecyclable oily wastewaters and sludges with waste gas treatment systems that exclude any environmental pollution by combustion products;
- reclaimed (recycled) industrial wastewater treatment facilities (purification and demineralization units (for example, brine from regenerating water softeners or blowdown from the operation of recirculating wet cooling towers);
- units for surface stormwater runoff treatment.

The main tailing management facilities are those for the concentrated spent process solutions treatment (for example, spent pickling solutions) and industrial wastewater sludges, since more than

80 % of soluble compounds are concentrated in the spent process solutions, and about the same amount in the industrial wastewater sludges. The treatment of this kind of waste alone largely solves the environmental pollution problem.

Tailing management facilities make the water industry system of an enterprise more complicated; the system turns into a chemical and engineering facility designed to produce water for the industrial water supply system and treat the resulting concentrates of demineralization plants, industrial wastewater sludges and other tailing.

Tailing management facilities at industrial enterprises require:

- some significant investment and operating costs;
- high-quality and expensive basic process and pumping equipment, instruments and meters, automation systems;
- highly qualified engineering and operations personnel.

3. Stages of Development of the Zero Liquid Discharge Systems in Russia

The first ZLD systems in the USSR were built to treat the liquid waste with a low radioactivity level, abroad — a reclaimed industrial wastewater treatment facility for municipal wastewater across Lake Tahoe (USA) [5] and a unit for the treatment of saline mine waters in Upper Silesia (Poland) [6, 7]. They were used as the prototype of the modern ZLD systems.

The entire experience of the construction and operation of ZLD systems of our country's industrial enterprises can be divided into three stages, from 1973 to 1990, from 1991 to 2000, from 2001 to the present.

The first stage, especially in the 1980s, was typical of the rapid construction of ZLD systems. The systems created are well described in the papers of that time [8, 9]. We should recall that in 1973, for the first time in the world's practice, in the Verkh-Isetsky Metallurgical Plant in the city of Sverdlovsk (now NLMK Group's VIZ-Steel in the city of Yekaterinburg), a ZLD system developed by V. I. Aksenov and colleagues in the cold rolled transformer steel workshop was launched and successfully operated [10, 11].

The estimated cost of the system at that time amounted to 29 million roubles. Almost at full capacity, it was possible to launch the entire group of treatment facilities in six months due to such gifted water engineers as Yu. V. Bobylev and his colleagues. At that time, the plant manager V. S. Ozhiganov provided invaluable assistance. It is impossible to overestimate the obtained experience of using ZLD systems in domestic and foreign practices.

During the second stage after the collapse of the USSR in 1991, the ZLD systems activities were practically ceased.

By the beginning of the third stage, the main production facilities of the Russian industrial enterprises, including almost all of the ZLD systems of industrial enterprises created during the Soviet Union, were physically and morally obsolete. The decline in the water industry led to the fact that at present in Russia, according to official data, only 11 % of wastewater discharged into water bodies meets all the regulatory requirements. In our opinion, the current status is even worse.

4. An Example of Acid Wastewater Treatment Technology as Part of a Zero Liquid Discharge System

As an example, let us consider a facility for the treatment of chemically contaminated acid ferrous-containing wastewater generated during the carbon steel pickling operation (Figure 1).

The chemically polluted wastewater purification technology at the initial stage of treatment involves wastewater blending followed by a uniform supply to the mixer for reagent treatment. Depending on the composition of the initial flow and process problems to be solved, some alkaline reagents (calcium hydroxide, sodium hydroxide, sodium carbonate), ferrous-containing coagulant, flocculant and other reagents can be applied to the flow treatment.

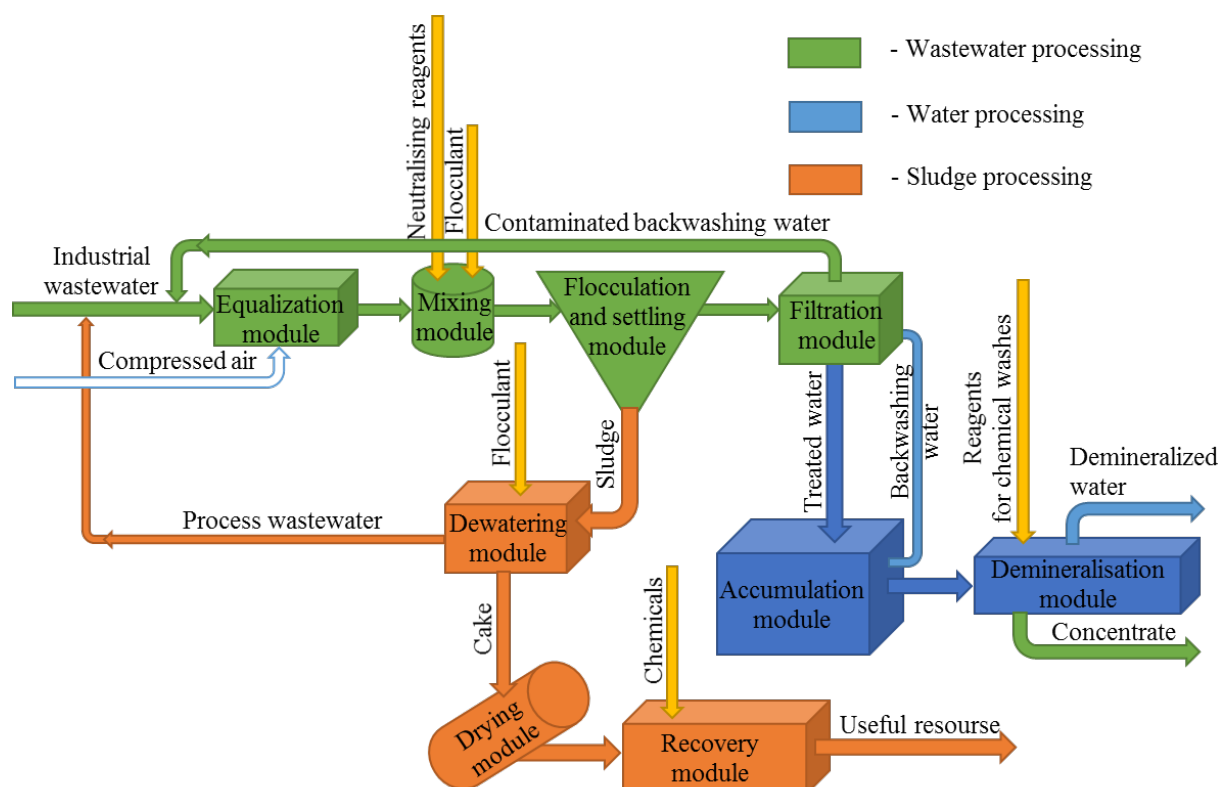


Figure 1. Process flow diagram of a facility for the treatment of the acid ferrous-containing wastewater generated during the carbon steel pickling.

The water treated with reagents enters the flocculation and settling module, where the main amount of toxic pollutants is removed from the discharge. At the same time, the wastewater flocculation and sedimentation facilities can be very diverse, e. g. free-standing and combined with settling tanks of the flocculation chamber, clarifiers of various designs, clarifiers with a suspended sediment layer etc.

For the purification of clarified water, deep bed sand filters with various designs or ultrafiltration units are arranged (filtration module).

Usually, water cannot be reused due to the water quality after a physical and chemical treatment with by the salt component content; therefore a water demineralization module is needed.

To obtain the demineralized water, the filtered water is directed to a demineralization module (a reverse osmosis system or an evaporator). Then, the demineralized water is fed for reuse (steam generation in the installation of steam boilers, use in pickling plants, or for other purposes). The resulting salt concentrate shall be recovered [12–14].

The sludge from the flocculation and settling module is sent to the dewatering module. After that, the cake (dewatered sludge) is dried in drying module, if necessary; the cake (sludge) composition is adjusted at the recovery module, and then the cake (sludge) sent for recycling.

5. Local Zero Liquid Discharge Systems

The capacity of the first ZLD systems of industrial enterprises were up to several hundred cubic meters per hour, since at that time it was possible to construct relatively economical multi-stage evaporators with only high productivity.

The mass implementation in the last 15–20 years in various industries of falling film evaporators, without and with vapor compression, heat pumps, membrane systems and other equipment gave an impetus to the development of energy-efficient evaporation facilities [15] and membrane facilities

[16–18] with a capacity from 10 to 4,000 l/h. Such fully automated units with low productivity are developed and manufactured by companies in Germany (H2O GmbH [19] etc.), France (Degremont Technologies [20] etc.) Israel (IDE Technologies [21] etc.), United states (Aquatech [22], Oasys Water [23] etc.), and other countries. As a result, it is now possible to create local ZLD systems for an individual plant or a industrial site of an enterprise instead of central ZLD systems for a whole enterprise.

Local ZLD systems have several significant advantages:

- in introducing local ZLD systems with the installation of demineralization at any separate production site during the purification of the resulting industrial wastewater, a concentrate will be formed, which can be recycled or returned to the process. For example, the concentrate of reverse osmosis unit, with which the rinsing water of the chrome-plating process are treated, and can be returned to a plating coating bath;
- the demineralized water produced at the local desalination unit as part of the local ZLD system can be immediately returned to the process. At the same time, the replacement of demineralized process water can significantly enhance the quality of products (for example, galvanic and paint-and-lacquer coatings);
- gradual elimination of the chemically polluted and (or) mineralized wastewaters from the industrial enterprise discharge including the treatment of those wastewaters at local treatment facilities increases the efficiency and reliability of the end-of-pipe wastewater treatment plant of industrial enterprise and reduces the man-induced impact on the environment;
- the creation of local ZLD systems requires smaller investment and subsequent operating costs, and also makes it possible to reduce the implementation of a ZLD system investment project.

6. Conclusion

In conclusion, it should be noted that currently Russian industrial enterprises lose the leading position in the creation of ZLD systems. While, virtually, no such systems have been created in Russia in the last five years, in the EU and countries and the USA there are thousands of such systems were put into operation. The reason for lagging behind is due to the lack of economic incentives for industrial enterprises. Let us hope that the situation will somehow change after the entry into force of all the new provisions of the federal law of Russian Federation «On Environmental Protection» and other legislation governing the introduction of the best available techniques (BAT) with a gradual increase in environmental charges and penalties for environmental law violations.

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